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Latest developments on the European eco-innovation scheme for reducing CO_2 emissions from vehicles: average input data for simplified calculations

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Abstract

This paper focuses on the latest developments in the European eco-innovation scheme for reducing CO_2 emissions from vehicles. In order to meet manufacturers' specific CO_2 emissions targets, Regulation (EC) No. 443/2009 and Regulation (EU) No. 520/2011 provide the opportunity for automotive manufacturers to take into account CO_2 savings from innovative technologies, "eco-innovations", which cannot demonstrate their CO_2-reducing effects under the test procedure used for vehicle type approval.
The process of approval of applications for eco-innovations is illustrated and some relevant examples are given. In order to simplify the process a key aspect is identified in the availability of average data that could be used for simplified calculations of the CO_2 savings of eco-innovative technologies. To address this need, the paper analyses the current dataset and presents new average values for the ambient temperature for driving vehicles. The methodology to evaluate these new values is presented and discussed. Average data that might be needed in the near future are also identified.

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Keywords: transport technologies; CO_2 emissions; energy efficiency; real world driving; eco-innovation

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1. Introduction

The European Union (EU) is committed to reducing greenhouse gas (GHG) emissions under the Europe 2020 Strategy (European Commission, 2010) and the Kyoto Protocol's second period (2013-2020). The EU is showing that emission cuts may support energy efficiency objectives as well as the reduction of energy dependence, and that they are not conflicting with economic growth: since 1990 the emissions has been reduced while expanding the economy. The challenge for all the policy sectors is to propose objectives and develop and implement efficient regulatory tools to meet the GHG reduction targets while stimulating innovation and economic growth.

It has been demonstrated that the second biggest source of GHG emissions in the EU is the transport sector; in particular road transport is responsible for more than two thirds of transport-related GHG emissions (European Commission, 2015). Transport is the only sector that increased emissions in the EU over the period 1990-2012: an increase of over 14%, yet with a downward trend since 2007 (European Commission, 2014). Passenger cars alone represent around 12% of total European CO_2 emissions (Hill et al., 2012). A range of policies aiming to lower emissions from the transport sector has been adopted by the EU (European Commission, 2011). For example, the EU legislation sets binding emission CO_2 targets for new passenger car (M1) and light commercial vehicle (N1) fleets (European Commission, 2009, European Commission, 2011). In 2015, newly registered cars were required to emit no more than an average of 130 grams of CO_2 per kilometre (gCO_2/km), expressed as fleet average per car manufacturer. By 2021, phased in from 2020, the objective for all new cars is 95 grams of CO_2 per kilometre. Compared with the 2007 fleet average, the 2015 and 2021 targets represent reductions of 18% and 40% respectively. Light commercial vehicle (N1) fleets are also required to meet average fleet target of 175 gCO_2/km by 2017 and 147 g CO_2/km by 2020. This legislation is the cornerstone of the EU's strategy to improve the fuel economy of cars and vans sold on the European market.

The technical procedures to assess the CO_2 performance of cars and vans in Europe are twofold. First, the traditional driving cycle used for type approval measures of the CO_2 emissions under reference conditions, i.e. the New European Driving Cycle (NEDC). Because of the inadequacy of the NEDC to simulate actual vehicle performance (Meyer and Wessely, 2009; Fontaras and Samaras, 2010; Weiss et al., 2011; Fontaras and Dilara, 2012; Sileghem et al., 2014; Martin et al., 2015) additional procedures – the so called eco-innovation scheme (European Commission, 2011; European Commission, 2014) – have been defined to assess the performance of technologies whose effects cannot be observed or quantified properly while driving the vehicle on the laboratory cycle, e.g. electrical consumption in real-word conditions or the use of ambient energy sources.

Applications for eco-innovations may be submitted by both vehicle manufacturers and suppliers. The application should include the necessary evidence that the eligibility criteria are fully met, including a methodology for measuring the CO_2 savings from the innovative technology (European Commission, 2011). The Commission Decision to approve the technology as eco-innovation shall specify the information required for the certification of the CO_2 savings and it may be used by manufacturers for the purpose of certifying the CO_2 savings as part of the type approval process. The maximum savings that a manufacturer may take into account for reducing the average emissions in a given calendar year is 7 g CO_2/km.

The approved testing methodologies for the quantification of the CO_2 savings are often based on input data which represent mean European conditions. These average values are very useful for the simplification of the calculations of the CO_2 savings of eco-innovations. In fact, the availability of such data may drastically reduce the amount of data and calculations that the applicants need to provide in support to their proposed methodology. The definition of new values for mean European conditions can also further stimulate the development of new methodologies for which these data are a necessary input.

The present paper attempts to tackle the need for new average values for mean EU conditions by examining the current eco-innovation dataset and identifying the data that might be required in the future. The paper proposes a methodology to define one of the missing average values, i.e. the European ambient temperature for driving vehicles. The approach followed in the proposed methodology can be used as reference for the definition of other missing values for mean European conditions that might be required in the future.

2. Methods

2.1. Legal background

Regulation (EU) No. 725/2011 and Regulation (EU) 427/2014 establish a procedure for the approval and certification of innovative technologies for reducing CO_2 emissions from passenger cars and light commercial vehicles pursuant to Regulation (EC) No. 443/2009 and Regulation (EU) No. 510/2011. These Regulations specify the eligibility criteria and sets out the applications procedure. The Technical Guidelines for the preparation of applications for the approval of innovative technologies provide additional information on how to prepare the applications as well as practical examples of potential technologies and testing methodologies. As of September 2015 twelve applications for eco-innovation have been approved, seven applications are under assessment and several applications are expected to be submitted within the near future. The approved technologies are currently concerning the improvement of electrical and mechanical components, the storage and use of wasted energy and the use of potential energy.

The application for an approval of an innovative technology as eco-innovation has to include a testing methodology that is suitable to determine and quantify the CO_2 saving effect of the technology. The methodology should provide accurate and verifiable results. In principle, a measurement, a modelling approach or a combination of both may be applied. Two different types of methodologies have been defined within the legislative framework: simplified approaches, based on predefined functions and average data, and comprehensive methodologies, defined with the use of extensive vehicle and hardware measurements. A mixture of the 'comprehensive methodology' and the 'simplified approach' is in principle possible. A list of approved eco-innovative technologies and their corresponding testing methodologies is presented in Table 1. Both simplified approaches and comprehensive methodologies are normally based on input data which represent values for mean European conditions.

Table 1. Summary of approved eco-innovative technologies and corresponding type of methodology.

Eco-innovative technology	Applicant	Type of methodology
LED lighting	AUDI AG	Comprehensive
Efficient alternator	Valeo Equipments Electriques Moteur	Simplified
Engine compartment encapsulation	Daimler AG	Comprehensive
Navigation-based preconditioning of battery state of charge	Robert Bosch Car Multimedia GmbH	Comprehensive
LED lighting	Automotive Lighting Reutlingen GmbH	Simplified
Efficient alternator	Denso Corporation	Simplified
Battery charging solar roof	Webasto Roof & Components SE	Simplified
Efficient alternator	Robert Bosch GmbH	Simplified
LED lighting	Daimler AG	Simplified
Battery charging solar roof	Asola Technologies GmbH	Simplified
Efficient alternator	Mitsubishi Electric Automotive Europe BV	Simplified
Coasting	Porsche AG	Comprehensive

2.2. Methodology and data sources

The paper analyses the current state of the average input data for mean European conditions which are required for the calculation of the eco-innovation CO_2 savings. For every approval decision the testing methodology is analysed and the required average data are identified. From the results of this analysis, a list of average data for each technology (e.g. efficient alternator or LED lighting system) has thus been derived.

Considering future technologies and latest developments in the EU regulation on eco-innovations, data that might be required in the future are identified. A methodology is presented to define one of the missing data, which is the average European air temperature for driving vehicles.

Our methodology for the definition of the average European temperature for driving vehicles is based on a number of steps. The first step is the evaluation of the monthly EU air temperatures for each member state. These values were calculated using the operational forecast data from the European Centre for Medium-range Weather Forecast (ECMWF CY41R1 Official IFS Documentation, 2015). The advantage of using these data is the spatial homogeneity and relatively high spatial resolution. Air temperature is available with a time resolution of 3 hours and a spatial resolution of 7.5 arc-minutes (about 14km) worldwide. For this study we used data for the period 2010-2013. From the 3-hourly time series we calculated the average of each time during the day for each month, obtaining 8 daily values for each month.

A gridded data set of temperature for each country is not necessarily representative of typical conditions, since some areas have much higher density of cars than others. In a second step we employed land cover data from the CORINE land cover database (Corine Land Cover 2006 raster data, 2015) to identify urban areas. The CORINE data were reprojected onto a latitude/longitude grid and aggregated on the 7.5’ grid of the ECMWF temperature data. Grid cells with less than 5% urban area density were excluded on the assumption that such areas have low population and hence low driving car density. Finally, the remaining grid cells were averaged over each country.

The resulting 3-hourly monthly temperatures were then weighted based on daily driving time distribution. The daily driving time distribution represents the percentage of cars which are actually being driven at a given time. The 3-hourly daily circulating time distribution has been derived from two large vehicles activity datasets of two Italian mid-sized provinces (i.e. Modena and Florence) which were purchased from a private company (Octo Telematics Italia S.r.l., 2015). These sets of data were extracted from the company data pool according to specific criteria in order to obtain a sample representative of urban driving conditions in those geographical areas. The vehicle activity data were acquired by means of GPS devices installed on the vehicles and connected via GSM to a remote storage unit. The acquisition devices anonymously records time, GPS position coordinates, engine status, instantaneous speed and cumulative distance and this enables to reconstruct in detail the driving pattern of each of the monitored vehicles. The two datasets cover a period of one month (i.e. May 2011) and were initially referred to 52,834 vehicles for Modena (12.0% of the total fleet of the province) and 40,459 vehicles for Florence (5.9% of the total fleet of the province). The analysis is then restricted to 16,263 vehicles (30.7% of the original sample) for the province of Modena and to 12,422 vehicles (30.7% of the original size) for the province of Florence. The analysed cumulative distance amounts to 15.0 million km and 20.6 million km, for Modena and Florence respectively, corresponding to approximately 16.0 million and 32.0 million records and 2.64 million and 1.87 million trips and parking events. The analysed activity data refer to the month of May and have been assumed to be representative of the driving behaviour also for the other months of the year. This means that in this analysis the seasonal variation of the driving habits, which however is assumed to be rather limited even for different countries (Marconi et al., 2004), has not been considered. The databases have been analysed by means of in-house built scripts in MATLAB® (Mathworks Inc., 2015), according to the procedure described in (De Gennaro et al., 2014, 2015), in order to characterise the urban mobility in the analysed areas and support the definition, assessment and development of future energy and transport policy.

The average monthly temperatures for each Member State were then weighted on their corresponding average number of circulating cars to obtain the average monthly temperatures for the EU. The yearly average number of circulating cars for each member state was extracted from the database of the TRACCS EU project (TRACCS EU Project, 2015). The available data that were used are for the period 2008-2010. The number of circulating cars has been assumed constant during the year, as monthly differences are negligible for the purposes of this analysis.

3. Results

3.1. Analysis of the current dataset

To cover all the applications that have been approved, different parameters representing average mean European values have been defined. The current dataset includes physical characteristics of fuels, conversion coefficients, technical features of technologies and usage factors. Usage factors are to be intended as share of technologies usage in normal operations.

The current approved methodologies are based on average data resulting from studies of the European Commission and relevant stakeholders. The current values used in approved methodologies for the evaluation of the CO_2 savings of eco-innovations can be summarized as follows:

- Consumption of effective power for petrol, petrol turbo and diesel vehicles (V_{Pe}) [l/kWh]
- Efficiency of alternators for M1 vehicles (η_A) [-]
- Electrical solar efficiency system (η_{SS}) [-]
- UDC, EUDC and NEDC characteristics (distance (d) [m], duration (t) [s] and mean speed (v) [km/h])
- Densities (ρ) for petrol and diesel at 15 °C [kg/m^3]
- Conversion factor from fuel consumption to CO_2 emission for petrol and diesel vehicles (CF) [g CO_2/l]
- Usage factors for vehicle lighting ($UF_{lighting}$) and shading of solar panels (UF_{IR}) for M1 vehicles (UF) [-]
- Power requirements of halogen lighting types ($P_{lighting}$) [W],
- Total electric power requirements in NEDC (P_{TA}) and real-world driving (P_{RW}) [W]
- CO_2 correction coefficient due to extra mass (ΔCO_{2m}) [g CO_2/km kg]
- Average solar radiation (P_{SR}) [W/m^2]
- Correction coefficient for the usable share of incoming solar energy (SCC) [-]
- Ambient air temperature during parking time for M1 vehicles (T_{Adt}) [ºC]
- Share of vehicle stops (SVS) [%]
- Mileages for petrol, diesel and LPG M1 vehicles (M) [km/y]

The approved eco-innovative technologies and the average EU data upon which their methodology is based on are presented in Table 2.

Table 2. Average EU data for approved methodologies.

Eco-innovative technology	Average EU data
LED lighting	$P_{lighting}$, $UF_{lighting}$, V_{Pe}, CF, η_A, v_{NEDC}
Efficient alternator	P_{TA}, P_{RW}, V_{Pe}, CF, η_A, v_{NEDC}
Engine compartment encapsulation	SVS, T_{Adt}
Navigation-based preconditioning of battery state of charge	-
Battery charging solar roof	P_{SR}, UF_{IR}, η_{SS}, SCC, V_{Pe}, CF, η_A, M, ΔCO_{2m}
Coasting	-

3.2. Identification of average data for future applications

Different values for mean EU conditions might be useful in order to further stimulate the development of eco--innovations in cars and vans.

Regarding fuel characteristics, consumption of effective power and conversion factor from fuel consumption to CO_2 emission are needed also for LPG, E85 and CNG. Average values for hybrid vehicles might also be included. Currently fuel densities are only defined for Petrol and Diesel in the Technical Guidelines and they have never been used in approved methodologies. Anyway they might be useful in the future and the average density could also be defined for LPG and CNG. Other data that might be needed are the mileages for CNG and E85 vehicles. These missing data can be easily derived from technical legislation and reports (Hass, 2014) and can be included in the next version of the Technical Guidelines.

In addition, the eco-innovation dataset is currently only including mean ambient air temperature for parking vehicles. However, temperature during driving time would also be a necessary input data for technologies whose CO_2 benefits can be properly evaluated when vehicles are driving at temperatures which differ from the average value defined in the NEDC, e.g. at lower temperatures.

The introduction of a new eco-innovation regulation for light commercial vehicles (N1 vehicles) could lead to increased CO_2 savings from eco-innovation technologies. The mileage of these vehicles is usually much higher compared to private cars and this should be reflected in the usage factors of the technologies on such vehicles. To this purpose, complementary default data shall be developed to facilitate the possibility to apply with similar simplified approaches as already developed for passenger cars. For example, it would be useful to develop N1 usage factors for vehicle lighting or irradiation usage factor for battery charging solar roofs installed on N1 vehicles.

For the development of future data for mean EU conditions the involvement of several interested stakeholders is seen as beneficial; working groups can be established, especially when extensive experimental data is required.

3.3. Monthly EU temperatures during driving time

Following the methodology described in Chap. 2.2, the average monthly EU temperatures for circulating cars has been obtained. The resulting daily profile of circulating time distribution is shown in Figure 1. This daily profile is based on 3-hourly values which have been obtained by applying centered averages on the available 5-min data.

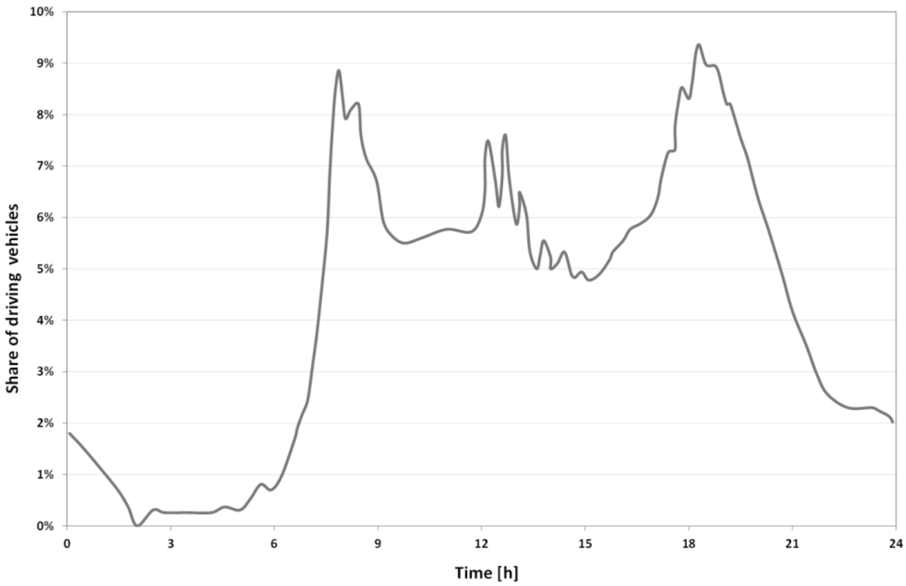

Fig. 1. Daily share of driving vehicles.

The resulting 3-hourly daily circulating time distribution is presented in Table 3.

Table 3. 3-hourly daily circulating time distribution.

Circulating time	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
Share of driving vehicles	1.64%	0.27%	1.81%	6.96%	6.04%	5.35%	7.89%	4.62%

Based on the daily circulating time distribution, the 3-hourly monthly temperatures were weighted and average monthly temperatures for each member state have been derived. The average monthly temperatures for each member state are presented in Figure 2. Pronounced temperature variability is observed among EU member states, especially in the winter period when the maximum difference reaches 22 °C.

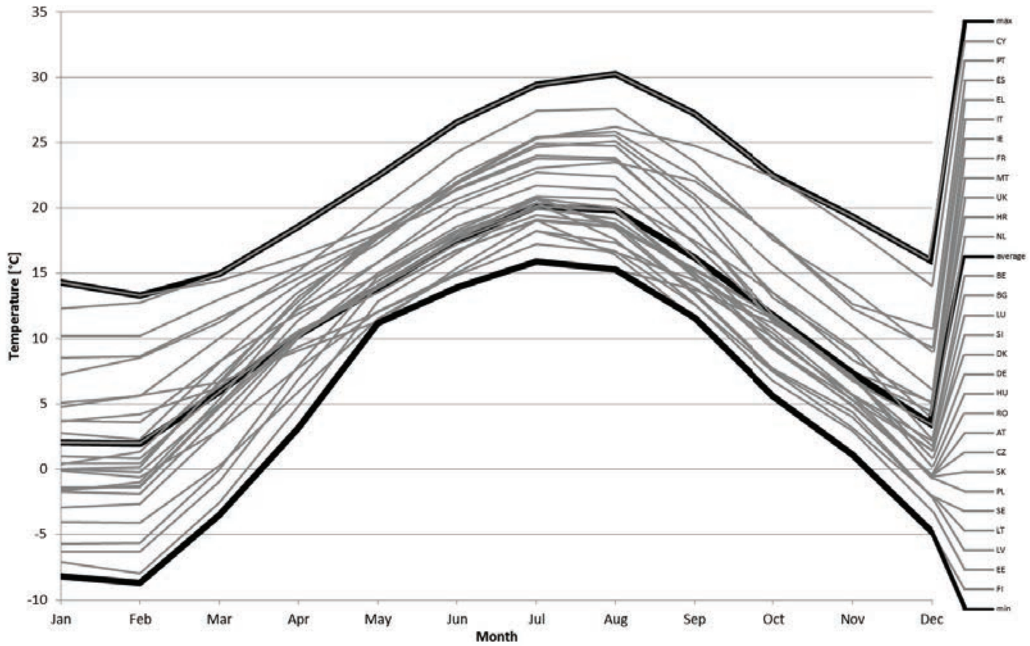

Fig. 2. Average monthly air temperature for each member state.

The average monthly temperatures for each Member State were then weighted on their corresponding average number of circulating cars (see Figure 3) and the average monthly EU temperatures for circulating cars have been derived (see Table 4). As it is possible to observe, even the monthly values have a significant variability that might have an impact in monthly-based calculations of CO_2 savings of certain innovative technologies.

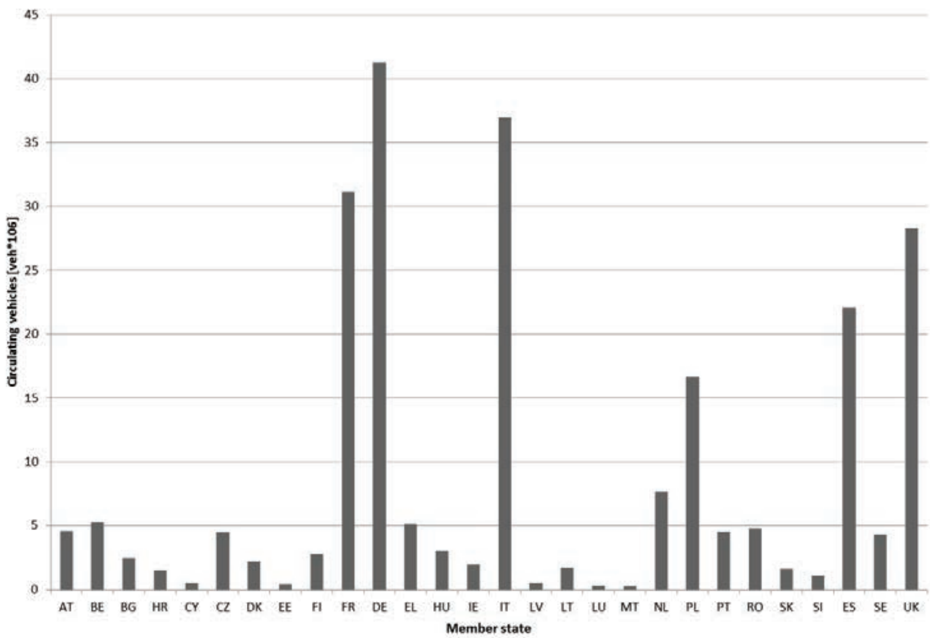

Fig. 3. Average number of circulating cars for each member state

Table 4. Average monthly EU temperatures for circulating cars.

Month	Temperature
January	3 °C
February	3 °C
March	7 °C
April	12 °C
May	15 °C
June	19 °C
July	22 °C
August	21 °C
September	17 °C
October	13 °C
November	8 °C
December	4 °C
Year	12 °C

4. Conclusions

In this study the current eco-innovation dataset has been analysed and data that might be required in the future have been identified. The main values that are needed refer to fuel characteristics, mileages, air temperatures and different parameters for eco-innovations on N1 vehicles. The paper proposes a methodology to define one of the missing values, i.e. the European ambient air temperature for driving vehicles. Monthly EU temperature values have been defined to address the potential need to have monthly-based calculations of CO_2 savings. The approach followed in the proposed methodology can be used as reference for the definition of other missing values for mean European conditions that might be required in the future.

Further research on the definition of missing data that has been identified in this study can be performed in the future. The definition of these data can further stimulate the development of new methodologies for which these data are a necessary input and can facilitate the adaptation of the eco-innovation scheme to the new eco-innovation regulation for light commercial vehicles.

For the development of future data for mean EU conditions the involvement of several interested stakeholders is seen as beneficial; working groups can be established, especially when extensive experimental data is required.

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Disclaimer

The views expressed here are purely those of the authors and may not, under any circumstances, be regarded as an official position of the European Commission.

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